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GROUND-BASED GRASSLANDS DATA TO SUPPORT REMOTE SENSING AND ECOSYSTEM MODELING OF TERRESTRIAL PRIMARY PRODUCTION[1]

R.J. Olson, J.M.O. Scurlock[2], R.S. Turner, and S.V. Jennings[3]
Oak Ridge National Laboratory
Post Office Box 2008, Mail Stop 6407
Oak Ridge, Tennessee 37831 (USA)

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ABSTRACT:

Estimating terrestrial net primary production (NPP) using remote-sensing tools and ecosystem models requires adequate ground-based measurements for calibration, parameterization, and validation. These data needs were strongly endorsed at a recent meeting of ecosystem modelers organized by the International Geosphere-Biosphere Programme's (IGBP's) Data and Information System (DIS) and its Global Analysis, Interpretation, and Modelling (GAIM) Task Force. To meet these needs, a multinational, multiagency project is being coordinated by the IGBP DIS to compile existing NPP data from field sites and to regionalize NPP point estimates to various-sized grid cells. Progress at Oak Ridge National Laboratory (ORNL) on compiling NPP data for grasslands as part of the IGBP DIS data initiative is described. Site data and associated documentation from diverse field studies are being acquired for selected grasslands and are being reviewed for completeness, consistency, and adequacy of documentation, including a description of sampling methods. Data are being compiled in a database with spatial, temporal, and thematic characteristics relevant to remote sensing and global modeling. NPP data are available from the ORNL Distributed Active Archive Center (DAAC) for biogeochemical dynamics. The ORNL DAAC is part of the Earth Observing System Data and Information System, of the U.S. National Aeronautics and Space Administration.

KEY WORDS: Grasslands, Terrestrial, Primary Production, NPP, Database, Modeling

1 - INTRODUCTION

Geographically referenced estimates of net primary production (NPP), including seasonal and interannual variability, are key components for modeling of the terrestrial carbon cycle and its response to climate change and CO_2 fertilization. Advances in global modeling and remote sensing of primary production are jeopardized by the lack of readily available data from field studies to parameterize and validate global ecosystem models. NPP data are important to diagnostic-parametric models (using satellite remote sensing), correlative-empirical models (based on climate regressions), or more mechanistic biogeochemical models.

Records of vegetation productivity began in earnest in the late 19th century for commercially related products (e.g., crops, forage, forestry), and some long-term data sets began this way (e.g., pasture productivity at Rothamstead, UK; rangeland forage production at Pawnee, USA). Other long-term ecological measurements commenced in the 1960s under programs such as the International Biological Program and in the 1970s under the U.S. Long-Term Ecological Research program. Today, data from many study sites worldwide are

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[2]King's College London, London, W8 7AH (England)
[3]The University of Tennessee, Knoxville, Tennessee 37996 (USA)

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scattered throughout the peer-reviewed literature as well as in government and other reports of limited circulation. Through the need for data to validate climate change models and through easy access to powerful personal computers and data networks, a detailed and representative global NPP database has been conceived.

During the past few years, a coordinated strategy to improve global estimates of terrestrial primary production through measurements and modeling has emerged. An essential part of this effort is compiling a reference database of NPP ground-based data to parameterize and validate global ecosystem models. The need for NPP data has been endorsed by the International Geosphere-Biosphere Programme's (IGBP's) scientific committees of Data and Information System (DIS), Global Analysis, Interpretation, and Modelling (GAIM); Global Change in Terrestrial Ecosystems (GCTE); and Biological Aspects of the Hydrological Cycle (BAHC) and by the International Council of Scientific Unions (ICSU) Scientific Committee on Problems of the Environment (SCOPE). In addition, the *Global Terrestrial Net Primary Productivity First Model Inter-Comparison Workshop*, hosted by the Potsdam Institut für Klimafolgenforschung (PIK) at Potsdam, Germany, in July 1994, resulted in a recommendation to develop and distribute a database of NPP data (Lurin et al., 1994). As a result of the recommendation, the *Global Primary Production Data Initiative Project Description* (Prince et al., 1995) was prepared and has been endorsed by a steering committee of representatives from the international groups listed above.

Global grasslands NPP reference data are being compiled by the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) as a component of the IGBP DIS data initiative. This paper summarizes the data initiative, describes the ORNL DAAC, and discusses the Grasslands NPP Database.

2 - DATA INITIATIVE

Key elements of the *Global Primary Production Data Initiative Project Description* (Prince et al., 1995) are summarized below.

2.1. Purpose

The proposed initiative will identify and compile reliable NPP and associated environmental data for field sites and will interpret the data to a range of spatial scales to provide parameterization and validation data needed in support of modeling global primary production and other applications.

2.2. Sources of Data

The NPP database will be compiled from existing data, as available from published literature, technical reports, or investigator files. The key to developing a successful NPP database will be to fully document the data and their limitations (metadata), to strive for completeness, to identify inconsistencies, and to update the database as new data become available. To the extent possible, principal investigators will be contacted and asked for their cooperation in acquiring the most complete and up-to-date data. In addition, information will be included to give credit to the appropriate investigator when data are retrieved from the NPP database.

2.3. Criteria for Site Selection

Criteria for selecting and rejecting data are related to the intended use in validating NPP models. Criteria include adequacy of documentation, spatial coverage based on global vegetation types, spatial coverage based on regions in which NPP models disagree, and associated data necessary to allow scaling up, all emphasizing global coverage.

2.4. Database Development

For database development, emphasis is on variables needed to parameterize and validate NPP models, including aboveground and belowground NPP, standing crop biomass, leaf area index, and site characteristics such as meteorology, soils, vegetation, and management practices. Procedures have been established for reviewing data for correctness, consistency, and adequacy of associated documentation, including definition of units of measure, method, and site coordinates. Data processing includes performing quality-assurance checks, converting units and codes to common standards, potentially estimating missing attributes from secondary data sources, and entering data into a database system. Documentation, extracted from published reports and literature, defines the usability

and quality of the data. As necessary, original data compilers or other sources of information are contacted to resolve data questions.

2.5. Organization

The overall project includes identifying and compiling field data sets, developing and applying methods to scale field observations to larger grid cells, and storing and distributing data. These tasks are divided between four institutions having expertise in the appropriate field. ORNL, Oak Ridge, Tennessee, USA, is compiling field measurements of NPP for natural systems. The Geography Department of the University of Maryland (UMCP), College Park, Maryland, USA, is developing estimates of NPP for grid cells between 1 km^2 and 0.5° latitude by 0.5° longitude. The LERTS/CESBIO, Toulouse, France, is identifying large areas of agricultural crops for which yield and NPP data are available and can be extrapolated to grid cells. PIK, Potsdam, Germany, is compiling meteorology and other physical variables for the sites and cells associated with the other three tasks.

2.6. Database Access

PIK is providing an initial repository and access to the data by the modelers participating in the Potsdam workshops on NPP model intercomparisons. The ORNL DAAC for biogeochemical dynamics will provide long-term distribution and storage for the NPP data.

2.7. Project Management

Because of the international and multiagency aspects of the development and use of the NPP data, a steering committee representing the sponsoring organizations and a project team consisting of principal investigators at ORNL, UMCP, CESBIO, and PIK provide overall direction for planning and executing the NPP database project.

3 - ORNL DAAC FOR BIOGEOCHEMICAL DYNAMICS

The ORNL DAAC for biogeochemical dynamics is compiling the Grasslands NPP Database with support from the U.S. National Aeronautics and Space Administration (NASA). The ORNL DAAC is part of NASA's Earth Observing System Data and Information System (EOSDIS) Project, which forms an integral part of NASA's contribution to the U.S. Global Change Research Program. The ORNL DAAC provides information about the Earth's biogeochemical dynamics to scientists, policymakers, educators, and the general public. The DAAC includes data, extensive metadata, and value-added products from NASA's ground-based research programs and remotely sensed observations, as well as biogeochemical dynamics data collected by other agencies.

Data available from the ORNL DAAC are associated with the following projects:

- **FIFE** - The First ISLSCP (International Satellite Land Surface Climatology Project) Field Experiment Project was conducted on a prairie in Kansas to understand the biophysical processes controlling the fluxes of radiation, moisture, and carbon dioxide between the land surface and the atmosphere and to develop remote sensing methodologies for observing these processes.
- **OTTER** - The Oregon Transect Ecosystem Research Project estimated major fluxes of carbon, nitrogen, and water in forest ecosystems in Oregon using an ecosystem-process model driven by remotely sensed data.
- **BOREAS** - The Boreal Ecosystem-Atmosphere Study Project investigates the interactions between the boreal forest and the atmosphere in Canada using surface, airborne, and satellite observations to characterize biological and physical processes that govern the exchange of energy, water, heat, carbon, and trace gases.

Access to these data, to data held by the ORNL Carbon Dioxide Information Analysis Center, and to the Grasslands NPP Database is through the ORNL DAAC World Wide Web home page (Uniform Resource Locator: http://www-eosdis.ornl.gov). Access requires a computer with a graphical user interface (e.g., Netscape or Mosaic running under Windows) and relatively fast data transfer to view all graphics. Users may also order data sets via telnet and a graphical user interface. For users without ready access to on-line communications, the User Services Office of the ORNL DAAC may be contacted by phone (423-241-3952), fax (423-574-4665), or electronic mail (ornldaac@ornl.gov), and the staff will distribute data on various media.

4 - GRASSLANDS NPP DATABASE

4.1. Database Contents

Data from SCOPE grassland sites were selected for initial entry into the Grasslands NPP Database based on their extensive use and acceptance by the modeling community. A collaborative SCOPE Project (Breymeyer and Melillo, 1991) included a Grasslands Modeling Group that assembled detailed and long-term data from both temperate and tropical grasslands. These data were used with the CENTURY plant-soil ecosystem model to simulate response to climate change scenarios for 31 grassland sites worldwide (Parton et al., 1993; Parton et al., 1995).

The Grasslands NPP Database currently consists of detailed biomass dynamics, climate, and site characteristics data for 13 grassland sites (Table 1). There are more than 150 site-year-treatment combinations of biomass measurements and an average of 30 years of monthly climate data for each site. The sites were related to bioclimatic ecoregions based upon a modification of Bailey ecoregions (Bailey, 1989; Parton et al., 1995).

An integral part of the data compilation was to use consistent and standard methods to estimate NPP from the field data. Often investigators have estimated NPP, using methods that may seriously underestimate NPP, or they have not defined the method that was used. NPP was recalculated for sites in the Grasslands NPP Database by using standard methods as permitted by available data. For example, probably the most universal estimate of NPP is based on the maximum or peak live aboveground biomass (referred to as ANPP in Table 1); however, six of the sites had more complete measurements that allowed NPP to be estimated from the sum of positive growth increments of both aboveground and belowground components (referred to as NPP in Table 1) by using a method developed by the International Biological Program (Milner and Hughes, 1968). In addition, checks were performed to ensure that biomass was expressed as g m^{-2} and NPP as gC m^{-2} and files were compiled through the use of common formats. Other important components of the database include an abstract, investigator contact information, and key references for each site.

Table 1. Estimates of grassland net primary production (gC m^{-2} yr^{-1}) by site within ecoregions including ANPP - aboveground net primary production estimated from peak aboveground live biomass and NPP - net primary production estimated from the sum of positive monthly increments of belowground and aboveground biomass for sites with adequate data.

Ecoregion	Site	Number of years	ANPP	NPP
Cold desert steppe	Shortandy, Kazakhstan	3	62	685
	Tumentsogt, Mongolia	9	78	
	Tuva, Russia	5	54	
	Xilingol, China	10	78	
Forest-meadow-paramo	Montecillos, Mexico	11	134	379
Humid savanna	Klong Hoi Khong, Thailand	6	159	369
	Lamto, Cote Ivoire	8	185	
Humid temperate prairie	Khomutov, Ukraine	4	164	
	Konza, USA	7	147	
	Kursk, Russia	30	165	553
	Otradnoe, Russia	4	109	226
Savanna	Nairobi, Kenya	10	106	163
Temperate dry steppe	Pawnee, USA	6	29	

4.2. Database Access

Users can access the Grasslands NPP Database via the ORNL DAAC home page. Extensive metadata, as briefly described here, is presented to the user to aid in selecting data. After reading a description of the database and its intended application for testing of models, the user can access a general review of methods and algorithms for estimating NPP from site data and a directory of terms and definitions. A summary table of sites enables the user to rapidly compare site characteristics (location, soil type, biome type, vegetation type and climate) and data availability (start and end dates and interval) in order to select suitable data sets according to modeling needs. A world map shows the locations of the grassland sites, as well as the list of sites, for which data are available. Upon the selection of an individual grassland site, a site summary is shown that includes information on how to contact the original source of the data. A more detailed text description of each site is available, as well as a list of references with abstracts. Finally, the user can review the actual biomass and climate data tables for the selected site.

4.3. Future Additions

The ORNL DAAC proposes to compile additional NPP data from selected field sites in grasslands, forests (primarily boreal and tropical), and other biomes. Currently, grasslands data from additional sites are being compiled. The Grasslands NPP Database is deficient in the dry-savanna bioclimatic region. Acquisition of data sets from the West African Sahelian region (Scholes and Walker, 1993) and continental Australia will be targeted to fill this gap. Another significant missing region in the present coverage of the database is the extensive area of woodland-grassland mosaic in Brazil (*cerrado* and *cerradao*). During the past 10-15 years, there have been several major syntheses on the productivity of terrestrial biomes (e.g., Lieth, 1975); these may serve as the pointers to publications containing details of NPP measurements. Candidate data sources to be added to the Grasslands NPP Database include the International Biological Program woodlands data (DeAngelis et al., 1981) and forest productivity data (Cannell, 1982). Field measurement data, however, are rarely published in tabular form; more usually, summary tables and graphs indicate what field data were collected. To acquire these detailed data, researchers must contact the principal investigator or an alternative person and the rights and benefits of reproducing the numerical data must be negotiated. This process is often time-consuming, requiring a high degree of interaction between the ORNL DAAC and the principal investigator. The authors encourage individuals to contact the ORNL DAAC who have NPP data collections that are available for archiving or those who have a desire to use the NPP data.

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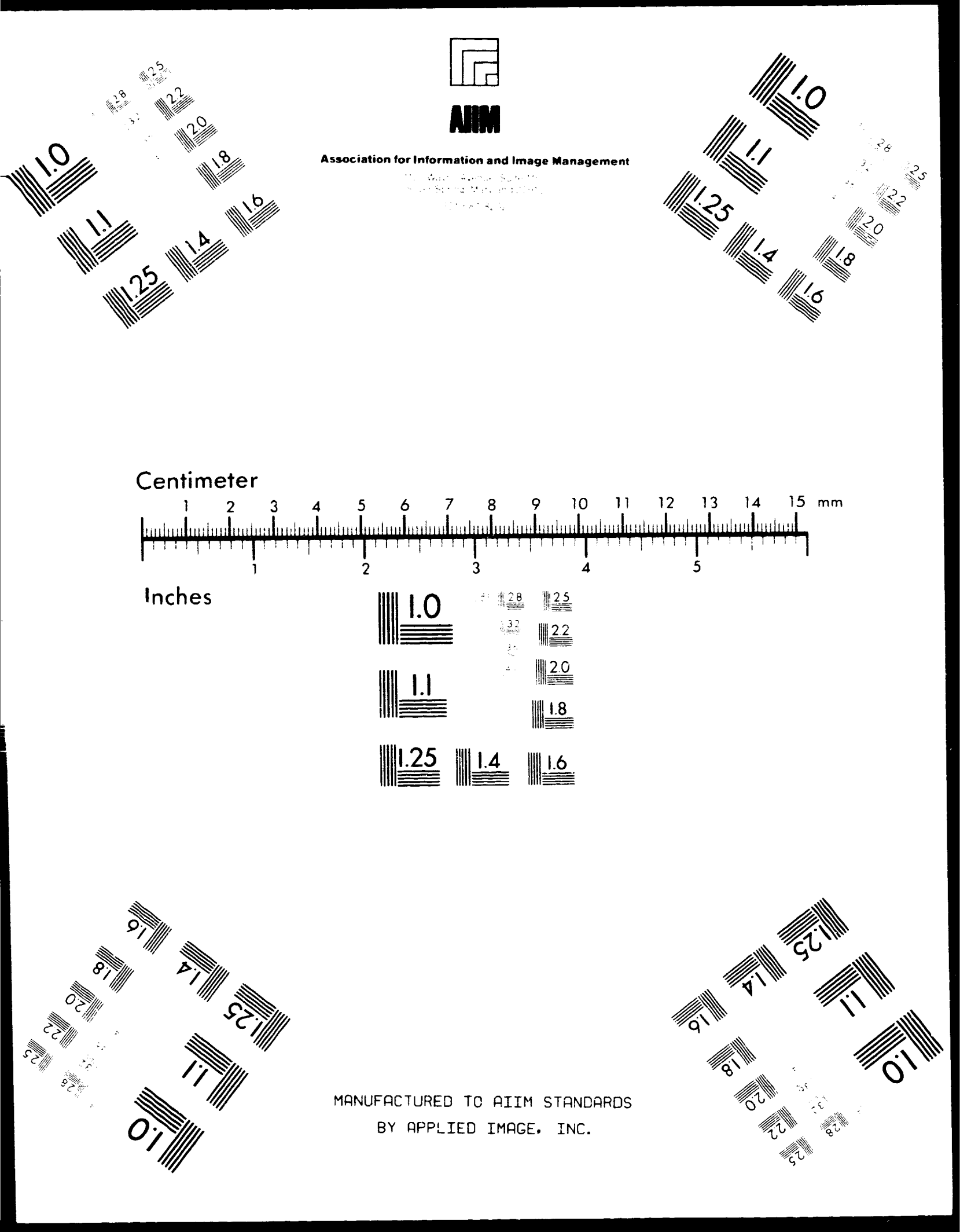
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